# RESEARCH PROPOSAL

## TITLE: IMPACT OF CLIMATE VARIABILITY ON AGRICULTURE IN HARYANA: A CASE STUDY OF PRODUCTION OF SELECTED RABI AND KHARIF CROPS OF REWARI DISTRICT

**FOR REGISTRATION TO THE DEGREE OF DOCTOR OF PHILOSOPHY**

**IN THE FACULTY OF SCIENCE**

IIS

(Deemed to be UNIVERSITY)
JAIPUR


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ICG/2018/26090

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JUNE 2019

## INTRODUCTION:

### CLIMATE CHANGE

Climate change is one of the important problems faced by today's world. Climate is the average atmospheric conditions prevailing in a particular area over a large period of time. Atmospheric conditions include elements like insolation, temperature, humidity, precipitation, air pressure winds etc. Climate change is therefore the process of long term changes in the atmosphere conditions or the weather phenomenon of a given area. According to Intergovernmental Panel on Climate Change, IPCC (2007) climate change refers to change in the state of climate that can be identified (by statistical tests) by changes in the mean and or the variability of its properties and that persists for an extended period, typically decades or longer. United Nations Framework Convention on Climate Change, UNFCC (1992) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climatic vulnerability observed over comparable period of time.

The 5$^{th}$ Intergovernmental Panel on Climate Change, IPCC report (2014) states that the combined land and ocean temperature data shows an increase of 0.89◦C over the period 1901-2012. The warmest 30 year period of the last 1400 years in the north hemisphere was 1983-2012.

The change in climate is a continuous and unequivocal process. The National Aeronautics and Space Administration, NASA (2014) describes climate change as the global phenomena of adding heat trapping gases to the earth's atmosphere by burning of fossil fuels. It includes processes like increase in temperature or global warming, rise in sea level, loss of ice mass, extreme weather events etc.

## CLIMATE VARIABILITY

The Intergovernmental Panel on Climate Change, IPCC (2013) defines Climate Variability as the variations in the mean state and other statistics such as standard deviation of the climate on all spatial and temporal scales beyond that of individual weather conditions. It can be explained as the fluctuation of climatic conditions around the average without causing the long-term average itself to change. The major causes of climate variability are the natural processes within the climate system and anthropogenic forces. It can be measured by observing the fluctuation in temperature, rainfall data and frequency of occurrence of extreme events. It may range from few months, seasons or years. The main impact of global warming is the increase in frequency of extreme weather events related to rainfall and temperature. (Karl *et al*., 2008). The last few decades experienced great variations in precipitation, particularly the south-west monsoon, sudden rise in temperature, change in radiation, extreme events such as cyclones etc.

## CAUSES OF GLOBAL CLIMATE CHANGE

Before the industrial revolution, the natural factors like variation in solar energy, volcanic eruptions, natural change in greenhouse gas concentration etc were considered as the main causes of climate change. But in the present scenario natural factors are dominated by human activities. The main causes of climate change can be categorized into natural causes and anthropogenic causes as follows:

a) Role of Sun- The Sun is the source of energy for earth. The output of solar energy is not constant; it varies over time to time. The combined effect of sun spot activity, sun's rotation and solar wind can be seen on the changes in the heat budget, the general circulation and the precipitation patterns on the earth.
b) The change in eccentricity of earth's orbit- The tilt of earth's angle varies slowly between 22.1◦ to 24.5◦ during a cycle of about 41,000 years. It affects the temperature distribution, seasons and general circulation. The ice age cycles of Milankovich are based on these orbital variations. The mean distance from the earth to the sun could vary with the change in eccentricity of the earth's orbit which could affect the temperature on the earth.
c) Ocean currents - Almost 71% of earth's surface is covered by ocean water. Oceans absorb two times more solar radiation as compared to the land surface or the atmosphere. Important climatic phenomenon like El-Nino is

the results of interaction of ocean and atmosphere. The concentration of carbon-dioxide in the atmosphere is also influenced by the oceans.

d) Volcanic eruptions_– Volcanic eruptions scatter ash, sulphur dioxide and dust particles in the atmosphere. The effect of volcanic eruptions is felt in local climates deeply, though their global impact is undetectable. The scattered particles act as reflectors of sun light.
e) Continental drift- The continental drift is responsible for the changes in physical features of landmass, their position and the movement of ocean currents and wind. Geophysicists explained the refined plate tectonic theory to support the crustal movements as the cause of climate change.
f) Anthropogenic causes-The human factors have major role in changing the climate of the earth. Human activities like burning of fossil fuels, industrial development, deforestation, construction work have greatly influenced the earth's climate. Greenhouse gases and aerosols alter the incoming solar radiation and outgoing infrared radiation and affect the balance of heat budget of the earth. Human activities have a warming influence on the climate.

## IMPACT OF CLIMATE VARIABILITY ON VULNERABILITY

Vulnerability of climate can be explained as the intensity of climate variation to which the system is exposed. The impact of climate change is uneven or varies from place to place because of the influence of various physical as well as human factors. It also depends on social, economical, political, and technological and development of environment of region. The developmental activities like industrialization, urbanization, deforestation, construction work have direct adverse impact on climate variation and increase the vulnerability. Vulnerability actually involves the exposure, the sensitivity and adaptability. Developing countries are more vulnerable to climate change than the develop nations. The develop nations are resourceful and have the capacity to manage the risk accordingly. The concept of vulnerability is helpful in planning the risk management strategies and reducing the impact of climate change and variability. Vulnerability is the base to decide the adaptation strategy to cope up with the influence of change of climate.

## CLIMATE CHANGE AND INDIA

India is famous for its vast geographical and topographical features which strongly influenced its climate also. The tropic of Cancer passes through the middle of India. It has the features of both tropical and sub tropical regions. The surface temperature has a rising trend of 0.6◦C over the past hundred years. India has large proportion of population which is responsible for over exploitation of resources. Due to this over exploitation of resources, we are actually destroying the natural resources. The process of urbanization, industrialization and modernization are the main reason behind the alarming environmental problems and climate change. The increase in pollution has adverse impact on nature, climate, agriculture bio-diversity and human life. Air pollution and water pollution are the burning problems of the world as well as of India. Severe weather events like Uttrakhand floods-landslides (2013), Chennai flood (2015) and drought (2016) are the examples of disasters caused by change in climate. According to World Bank, there will be an increase of 2°C in the world's average temperature in the next few decades. It is also going to influence the Indian monsoon mechanism which will directly affect the agriculture production and productivity of the country as India is agriculture based country and about 60% of the crop area depends on rain. The future impacts of climate change, identified by the Government of India's National Communications in 2012 include:

1. Impact Assessment on Water Resources -Impacts of climate change and climate variability on the water resources are likely to affect irrigated agriculture, installed power capacity, environmental flows in the dry season and higher flows during the wet season, thereby causing severe droughts and flood problems in urban and rural areas. The per capita availability of water was 5177 m3 /capita/year in 1951. This value is likely to reduce to below 1140 m3 /year by 2050.

2. Impact Assessment on Forests -Forests are likely to be more vulnerable to climate change.

3. Impact Assessment on Indian Agriculture-The 1°C increase in mean temperature alone could lead to a decrease of 6 million tonnes of wheat production. This loss is likely to increase to 27.5 million tonnes in case of a 5°C increase in mean temperature.

4. Impact Assessment on Human Health Heat stresses, vector borne diseases, and water contamination are some of the main health impacts projected due to climate change. Warmer temperature, shifting rainfall patterns, and

increasing humidity affect the transmission of diseases by vectors like mosquitoes.

5. Climate change and sea level rise - Sea level rise will modify the configuration of the Indian coastline and create a lot of environmental and societal problems.

6. Erratic monsoon with serious effects on rain-fed agriculture, peninsular rivers, water and power supply

7. Studies indicate that over 50% of India‘s forests are likely to experience shift in forest types, adversely impacting associated biodiversity, regional climate dynamics as well as livelihoods based on forest products.

8. Vulnerability to extreme events would affect arid and semi-arid zones, of which nearly two-thirds are drought-prone.

## CLIMATE VARIABILITY AND AGRICULTURE

Agriculture is a primary activity which directly depends on nature or climate of a specific area. The variety of crops requires different atmospheric conditions which include temperature, rainfall, sun light, humidity, wind conditions etc. Relevant climatic conditions are very much essential for quality and quantity production. The wide variety of climatic features provides large opportunities to Indian farmers to grow variety of crops. The Indian climate has dominant influence of south west monsoon which is responsible for majority of rainfall in the country. India receives about 80% of its rainfall in the month of June-September. Therefore Indian farmers have to plan their farming activities according to the prevailing climatic conditions. All important physiological processes such as photosynthesis, respiration, and grain formation require moisture. Therefore water is an essential requirement of agriculture sector. For India as a whole mean annual temperature shows a significant warming trend of 0.51 degrees Celsius per 100 years during the period 1901-2007 (Kothawale et al., 2010). Agriculture represents 35 percent of India’s GNP and sustains the livelihoods of nearly 75 percent of the population ( Kalra *et al.* 2003). This sector is also highly dependent on the South West monsoon (June-September), while 60 percent of the crop area under rain fed agriculture is in areas highly vulnerable to climate variability and change (National Communication on Climate Change, 2004).

## CLIMATE VARIABILITY IN HARYANA

Haryana came into existence as an independent state on 1st November 1966 on linguistic and cultural basis. Earlier it was the part of the former state of Eastern Punjab. It is situated on the northern part of India and surrounds Delhi on three sides. The river Yamuna flows on the eastern side of the state. Punjab and Himachal Pradesh are situated on its northern borders and Rajasthan shares its boundary on west and south. It has 22 districts and shares its capital Chandigarh with Punjab. Haryana is an agriculture based state where almost 85% of its land is under cultivation. The climate of Haryana is arid and semi arid. It is hot in summers and mild in winters. Major crops grown in Haryana are wheat, rice, sugarcane, cotton, Bajra, pulses etc. According to the vision document of the Haryana government, the state is experiencing an increasing trend of about 1◦C to 1.2◦C in maximum and minimum temperature in the past decades. The mean annual rainfall shows decreasing aspects of 3% in the mid century and increasing trend of 17% by the end of the century. ). Haryana shows high variation and poor distribution of rainfall during the monsoon season, it is major cause of crop failure and poor crop productivity during kharif season under dryland conditions (Singh *et al*, 2006) The changing pattern of Haryana climate thus, calls for reviewing the agricultural strategies and research priorities for sustainable and climate resilient agriculture. Rewari was carved out of Gurgaon by the Government of Haryana on 1 November 1989. About 83.79% of its land is used for agriculture. Rewari is deficient in rainfall and has to depend on manual irrigation. The crops grown in Rewari can be classified into Kharif crops( Bajra, Jowar, Cotton ete) which are grown in the summer between June to October and Rabi crops (Wheat, Mustard, Gram etc) which are grown in winter between November to April/May.

## ADAPTATION STRATEGY FOR CLIMATE VARIABILITY

The Intergovernmental Panel on Climate Change, IPCC (2007) defined Adaptation as "The result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state."

It is the process which prevents or reduces the adverse effects of a system by adopting certain changes. The impact of climate change is predicted to be more intense in future, so adaptation is the utmost need for today's world. It includes reducing the adverse or negative impact of climate change by implementing preventive methods. The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007) also accepts the mitigation strategies are not enough to save the earth from the ill effects of climate change. Policies to adapt the climate change are urgently needed for the whole world. Sustainable development is the most powerful weapon to defend against climate change impacts and reducing the vulnerability. Capacity building and can play an important role in this regard. Exposure to extreme events cannot be cope up without reducing vulnerability. Integrated adaptive measures could manage the risks of the climate change.

Some of the significant measures which can be adopted to minimize the impact of climate change on agriculture are:

- Management of salinity of soil
- Development of alternative irrigation methods
- Crop insurance facilities
- Shifting of growing crop season according to change in season
- Adopting new technologies and management programs to improve crop yield
- Selection of appropriate crops as per climatic conditions

# REVIEW OF LITERATURE

## PHENOMENON OF CLIMATE CHANGE

In the article **Das et al. (2012)** focus on the current understanding of powerlessness regarding environmental problems. The cause of climate change can be natural and manmade. Natural factors include variation in earth's orbital characteristics, atmospheric carbon dioxide variation, volcanic eruption, variation in solar output and plate tectonics. Milankovitch theory states that normal cyclical variation in three of the earth orbital characterizes are responsible for past climatic change. Over the past centuries, the concentration of carbon dioxide has been increasing in the atmosphere because of human activities. Explosive volcanic eruption eject sulphuric dioxide in atmosphere. Numerical climatic model suggest that a change of solar output of 1% per century would increase the earth's temperature by 0.5-1.0 ° Celsius. Plate tectonic reorients the position of continent, shape oceans and tear down mountains which also regulates the condition of the climate

In the paper **Oldenborgh et al. (2018)** explains the factors responsible for climate change. Global warming is the impact of decadal variability in weather processes, air pollution and increased amount of humidity. Decadal variability does not have an expression in pre monsoon heat in India. Air pollution prevents the sun light from reaching the ground, expressing a negative trend in maximum temperatures. Both, increase in humidity and aerosols from air pollution increases the health risks of heat waves. Humidity will probably continue to rise as irrigation expands further, though at a reduced rate, and sea surface temperature rises. The combination will result in a strong rise in the temperature of heat waves. The high humidity will make health effects worse, whereas decreased pollution would decrease the impacts. These health impacts can be reduced by providing early warning of a forecasted heat waves and by keeping parks and homeless shelters open on hottest days.

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# VULNERABILITY AND CLIMATE CHANGE

**Joel et al. (2001)** focus on the relationship between increase in global mean temperature and its impact. Regional climate have its reflection on physical and biological system rather than socioeconomic synthesis. Tropical glaciers, coral reefs, mangroves, ecotones and biodiversity hotspot are example of unique and threatened entities confined to narrow geographical ranges. The impact of climatic change is not even throughout the world. Developing countries are most vulnerable to climate change than develop countries. The frequency and magnitude of much extreme climate event increase even with a small temperature increase and will become greater at higher temperatures .Extreme climatic effects are more locally and could strongly affect specific region. Rapid and large increase in temperature would lead to large scale singularity in the climate system.

In the report**, Fischer et al. (2002)** explains the impact of climate change on agro-ecosystem with reference to the world food and agriculture system. It also includes the climate change impact on climate variability and variability of rain fed cereal production, changes in potential agriculture land. The article also explains the trends in food production, trade and consumption. Climate change also influences the social economic and environmental system end provide a framework for sustainable agriculture and rural development. The issue of climate change is global and involves complex interaction between climatic, environmental, economic, political, social and technological processes. There is a need to give more attention to climate change adaptation rather than mitigation. Highest priorities must be given to agricultural and rural sector for resource allocation and adoption of development policies.

**Patwardhan (2006)** describes the evolution of impact assessment approaches with reference to coastal impact of climate change and draw insights regarding methodological issues. Coastal zones are the first regions for which assessments of climate change as there is a direct link between global warming and rise in global mean sea level. Adaption policy must be given more importance than mitigation in the climate policy as adaption is linked to core development issues. Complete understanding of vulnerability and adaptive capacity is very important to attain the benefit of development projects. Care should be taken that infrastructure project may not lead to mal-adaptation with regards to future climatic change. The assessment and evolution of impact should focus on variable units of analysis. Climate policy should be based on developmental priorities and policies.

**Ramarao et al. (2016)** describes the vulnerability of agriculture to climate change and variability at the district level. The study emphasize on the importance of assessment of vulnerability to climate change to adopt appropriate strategies. Vulnerability index is constructed to identify intervention which is more specific to the particular region (district), help farmer to deal with future climate stress as well as with current climate variability. Indicator reflecting sensitivity, adaptive capacity of 572 districts are used to construct vulnerability index. Most of high vulnerable district are located in western and peninsular index. Indo-Gangetic plains have high adaptive capacity and low exposure which makes them less vulnerable. Districts with increasing annual rainfall trends can be more climate resilient.

## CONCEPT OF CLIMATIC VARIABILITY

The article by **Rind et al. (1993)** explains five hypothesized natural and anthropogenic causes of climate variability. It includes the inherent variability in atmosphere, inherent variability in the ocean system, solar variability, variability in volcanic aerosol and atmospheric trace gas variability. The inherent variability in the ocean system has the most influential impact in the adjacent areas. The solar variability and low latitude volcanic aerosol variability affect all latitudes where as trace gas variability is effective at high latitudes. The global mean decade to century scale variability is limited to 0.5 to 1.0°C during the Holocene age. The natural sources of climate variability will influence the future greenhouse warming.

**Sivakumar et al. (2005)** discussed the issue of climate variability in arid and semi-arid regions of the world. These regions comprise about 30% of the world total area with about 20% of the total world population. The arid and semi arid regions of Asia show the increasing trends of surface temperature. Despite of no noticeable change in the long term mean precipitation, many regions have shown the decreasing trend in rainfall in the past three decades. In Africa, the study shows visible changes in the frequency and intensity of extreme events. The regions of South America have strong impact of El Nino southern oscillation. The increase and decrease of rainfall depends on the warm and cold phases of the phenomenon. The agricultural production in Asia is very much influenced by the increase in temperature and the nature of monsoon. The climate change could have adverse influence in the regions of Africa. It can increase the frequency of extreme weather events which could affect the agriculture and water resources of the regions. The prescriptive and dynamic adaptation approach is the greatest need of present world.

**Dash et al. (2007)** describes the increasing trends of temperature over the past twenty five years. It also discusses the important climatic variations reflected during different seasons over different regions of India. The rise in minimum temperature has significant differences between the winter and post monsoon seasons. The whole country has been divided into two zones (north and south) by 21° N latitude to observe the climatic variability. The significant variations have been observed in minimum temperatures in North and South India. The aerosols, clouds and mesoscale flows around the Indian mountains are important deciding factors for regional climate in future. The impact of these variations on agricultural activities and human health are severe and varies in different regions. The article also emphasized the importance of mitigation and adaptation plans dealing with climate change for economic and social development of the region.

**Khan et al. (2009)** emphasized on the rising trends of temperature, increasing concentration of carbon di oxide and its impact on agriculture in India. The crop models which are used to assess the impact of climate change on agriculture shows region specific results. The accurate impact assessment demands the accuracy in assessing the degree of climate change. The huge genetic diversity of crops offers an alternate to the farmers to sustain the production by identifying suitable thermal and drought tolerant conditions. The suitable agronomic management options could sustain the yields which have been stagnated in some parts of north-west India. The increasing magnitude of droughts and floods could be identified by suitable management options. The climate change can be linked with other socio-economic and bio-physical aspects through crop simulation technique. It can effectively trace out the impact of climate change and offer suitable mitigation strategy to sustain the agricultural productivity. There is an urgent need to generate future scenarios for various agro-ecological regions to strengthen the socio-economic aspects of climate change.

**Friedrich et al. (2009)** reviews the role of Indian ocean on climatic phenomenon and processes influencing the climatic variability. The two important types of inter-annual variability in Indian ocean are El Nino-Southern Oscillation (ESNO) and Indian Ocean Dipole(IOD).IOD events depends on either ESNO or on eastern tropical preconditions. The sea surface temperature of Indian Ocean influences the monsoon mechanism as well as climatic variability. It forms the major warm pool of the earth and plays a deciding role in regional and global climate. The

climatological factors and upper ocean circulations in the Indian Ocean provide the background on which climate signals develop. Intra-seasonal variability, one of the primary processes affecting rainfall in the region has been discussed in the article. The El Nino– Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD; also called the Indian Ocean Zonal Mode) are the two main factors responsible for inter-annual climatic variability.

## IMPACT OF CLIMATE CHANGE IN WORLD, INDIA AND HARYANA

**Cynthia et al. (1994)** focused on regional and national level, crop growth models have been used to determine the effects of climate change scenario on crop yield in various geographical region. The projected temperature change in low latitude is lower than the world's average. The potential change in national grain crop yield is estimated using compatible crop models in 18 countries. It has been observed that when climate change is considered without direct CO2 effects on crop growth and water use, averaged national crop yields declined everywhere. Yields were positive in middle and high latitudes and negative in low latitude. Despite beneficial Co2 direct effect, the climate change indicated warming at low attitude brought accelerated growing period for crops and greater heat and water stream which results in great yield decrease. Farm level adaption and future technological yields improvements are also considered. It shows that increased global cereal production involves major and costly changes in agricultural system. Many countries in the tropical and sub-tropical zones appear more vulnerable to the potential impact of global warming. Cereal prices and the population at risk of hunger increased despite of adaption.

**John (2007)** explains the impact of climatic changes on small household and subsistence agriculture. The aggregate yield of crap shows a descending production trend. There is a need to recognize the complexity of their production system, incorporates non climatic stressors on rural lively hood. Coping strategies include change in relative importance of crop, livestock's species and won agricultural activities. Management of non-climatic stressors by government would forms a powerful strategy for assistive adaptation. The change in climate may also have adverse effect of the health of small holders. The future impacts of climate change on poor and rural people have tended to be concerned with extreme events.

In the report **Nelson et al. (2009)** analyze the impact of climate change and provide suggestion regarding the policy and program for adaption. Agriculture is extremely vulnerable to climate change. High temperature reduces the yield of desirable crop. The food quality report assesses the climate change impact on food security. The result of the report suggests that agriculture and human well-being will be negatively affected by climate change. The analysis suggest to design and implement good over all development policy and programs, greater investment in agriculture science, information sharing by transferring technology, improving statistical analysis etc. Community based adaptation strategies with more investment in agriculture sector to enhance food security should be implemented at local level.

**Idso et al. (2009)** states that the 2009 report of the Non-Governmental International Panel on Climate Change (NIPCC) has nine chapters. Each chapter emphasize on issues related to climate change. Computer climate models also have limitations in forecasting future climate condition. The report describe about the factors that reduce the earth temperature sensitivity to change in the atmospheric CO2 Empirical data on past temperature reveal no net warming over the past 29 year with no anthropogenic effect. Observation datas provide no evidence of anthropogenic global warming of $20^{th}$ century. The report also describes the influence of solar activity on climate change. The report debunks the fear of more flood, drought, storms, and heat waves due to global warming. Rising CO2 level promotes plant growth. Ecosystem biodiversity will increase in CO2 enriches the world. The CO2 include global warming would feed the increasing global population.

**Vijaya et al. (2018)** describes the consequence of climate change on bio diversity. Global warming will increase the occurrence and severity of weather events. Change in climate is a major threat to biodiversity. The shortage of water and increase in temperature effects the normal life cycle of plants. It also affects the bird life and animal distribution. Many human activities like industrial revolution, over exploitation of resources, deforestation, changing of land usage are responsible for global warming. Change in climate also leads to coral beaching, fish migration, rise in sea level, flood, ocean acidification etc. Many sensitive animals are going to extinct due to change in climate. Geo engineering and carbon

sequestration can reduce the effect of climate change. Public awareness and incentive can play a major role in reducing the impact of climate change.

**Leahy (2018)** states that the impact of global warming will be much greater than expectation. It is going to affect ecosystem, human communities and economies across the world. The impact may include severe climatic activities like storms, erratic weather conditions, strong heat waves and rise in sea level. Every nation agrees to stabilize the global warming at 2.7 degree Fahrenheit (1.5degree Celsius). Efforts like cutting the use of fossil fuels, use of carbon free energy sources, growing bio-energy crops and increase in forest area may be helpful in stabilizing the global warming. The challenges of phasing out the fossil fuel infrastructure, developing non fossil energy sources and large scale removal of carbon from atmosphere are not going to be easy. Forest could play very important role in cutting emission, so there is a strong need of reforestation and forest management

**Chattopadhyay et al. (1997)** discussed about the historic variation of seasonal Ep (evaporation) and PE (potential evapo-transpiration) over the past few decades for different station of India. The study also estimates the future change in PE due to greenhouse gas induce climate change in India. In spite of increasing in temperature in southern and central India in the recent decades in all seasons, there has been a decreasing trend in Ep and PE in all parts of India. These trends may affect the water resources and agricultural sector. Sufficient amount of rainfall may compensate evaporation loss and manage to solve the challenge of water resource and agricultural sector.

In the study **Kumar et al. (2006)** used an atmosphere and land surface model of limited area and high resolution to show the orographic pattern of summer monsoon precipitation. The extreme event analyses are very important for assessing the socio-economic impact of climate change. The study shows an increasing trend in both rainfall and temperature by the end of 21$^{st}$ century relative to baseline. It also imitates an all-round warming of Indian sub-continent with increasing greenhouse gas concentration. There is regional variation also in temperature and rainfall. West central India show maximum expected increase in rainfall. It is also observed that the minimum temperature is increasing more rapidly than maximum temperature. Its mean night temperature seems to be increasing at much higher rate. There is an increase in severe rainfall over Western Ghats and north-western Peninsula.

**Dash et al. (2007)** explains the variety of climatic features found in India. Being a vast country India has complex climatic conditions. Farmers and rural tribal people mostly depend on nature for their livelihood. They are more adversely affected by the change in climate. Poor people are more vulnerable to climate change. The important weather events affecting India are heat wave, cold wave, snow fall, flood, drought, monsoon depression and cyclones. Past studies shown that maximum temperature has positive trend whereas minimum temperature show very little trend. The opposite trends of increase and decrease in the minimum temperature in south and north India respectively have been observed. The increasing frequency of cyclonic storms crossing Indian coast are also noticeable. There is an increasing tendency in the rainfall during the post monsoon months where as it is has decreasing tendency in summer monsoon rainfall**.**

**Mall et al. (2007)** tells that agriculture plays very important role in overall economic and social well-being of India but still more than 60% of total cropped area is rainfall. Global warming is a great threat to India's food security. Now a days, many crop models are been used for assessing the impact of climate change on production. Increasing greenhouse concentration show marked increase in temperature and rainfall. Most of the crop model shows a decrease in duration and yield of crop as temperature increased in different part of India. The impact of climate change is observed more on "rabi" crop as composed to kharif crop. Adaptation strategies to mitigate the impact of climate include change in sowing date and awareness among the people.

**Raymond (2009)** states that agriculture plays very important role in developing. Economies like India. Agriculture in India makes about 20% of GDP and provides 52% of employment. The Semi-Ricardian study of Indian agriculture show significant negative effect of climate change. With a moderate long term climate change scenario, an increase in 2°c mean temperature and 7% precipitation may lead to losses of 10% of agriculture production. A panel of zoo district covering 1960-1999 is used to study the impact of climate change may reduce field by 4.5 to 9%, the long term climate change predicted yield falling by 25% or more. This negative impact could slow the pace of the poverty reduction process in India. Farmer in India are less able to adapt and mitigate climate change due to lack of finance and access to modern technologies. It is very important for the farmers to be able to adjust their farming practices and adopt new technology.

**Jha et al. (2011)** describes the relationship between variations in temperature and rainfall with that of wheat production. There is an increasing trend in maximum and minimum temperature data where as the winter rainfall is increasing in Haryana but decreasing in Bihar. The increasing temperature in the months of

harvesting season of wheat affects the total production adversely in Haryana and Bihar. Wheat cultivation is sensitive to climatic factors. This requires a longer period of low temperature during the sowing period for physiological growth and moderately high temperature at the time of ripening of grain (April). Therefore temperature is the most important factor in the cultivation of wheat. There is a need to develop risk management options like replacement of late sown wheat with other crops, scientific variety of seed which can tolerate more temperature etc.

**Birthal et al. (2014)** explains about the sensitivity of Indian agriculture to climate change. Agriculture plays important role in Indian economy. In the paper, the impact of climate change on agriculture was assessed by using district level panel data on 19 crops from 1969-70 to 2004-05. Higher growing period of temperature in kharif and rabi crop season adversely affects the agricultural productivity. The effect of rainfall is much lesser than that of temperature. The arid-semi-arid tropics are most vulnerable to climate change. Irrigation is important to mitigate the harmful effects of climate change. Improvement in water-use efficiency applying micro-irrigation technologies (like sprinkler and drip irrigation) and breeding of crop varieties could also be helpful in reducing the adverse effects if climate change.

**Jaba et al. (2016)** explains the impact of change in climate on agricultural productivity and food security. The productivity has reduced by 1-5% per decade over the last 30 years. The present situation is going to worsen the problems of hunger and malnutrition. Insect pests, one of the major hindrance in food production, are also sensitive to climate change. It will be important to keep ahead of undesirable pest adaptations, and consider global warming and climate change for planning research and development efforts for integrated pest management. Development of insects will be more in higher temperature. It calls an urgent need of improved approaches to respond to insect pests and a well develop scientific system of forecasting and predicting pest .An integrated pest and disease management system leading to sustainable crop production can play a key role in mitigating the damage done by insect pests.

**Kaur et al. (2017)** explains that Climate change plays significant role in Indian agriculture pattern. The geographical diversity of India influences the impact of climate change over the country. The basic element of climate i.e.-temperature and rain fall directly affect agricultural production and food security in India. From the last three decades, the average temperature has risen by 0.85°C. India has around 24.5% of total undernourished people of the world. In this report, the impact of climate change on agricultural production is analyzed by using ordinary least squares and two stage least square instrumental variable. The empirical study show that increase in deviation of average temperature has direct adverse impact on crop production as compared to that of rainfall. The food security could be maintained

in India by increasing public investment in agriculture, building of food stocks and undertaking direct investments to address food**.**

**Burgess et al. (2017)** shows the unequal effects of climate change on the population of developed countries and developing countries especially in rural and urban areas. The paper used district level daily weather and annual mortality data from 1957 to 2000. It tells that hot days lead to much greater increases in the death rate in India than in the US that too in rural areas. Weather extremes can potentially harm human health both directly (through physiological stress, for example) and indirectly (because of lower incomes or those who work in weather-dependent occupations). Living in an urban area even at low levels of income appears to have a protection from mortality impacts of hot weather. The income effect of hot weather are more severe for rural versus urban populations. Hot weather sharply depresses agricultural yields and the wages of agricultural laborers in rural areas. India's rural bank branch expansion program (which ran from 1977to 1990) mitigated substantially the impact of hot weather on mortality.

In the paper, **Sihag (2017)** describes that a Reconnaissance survey was conducted in Haryana to know the impact of climate change on the crop. In this study meteorology data and production data were taken as secondary data which were based on weather and crop productivity aspect. A structured and standardized questionnaire was used for data collection. The result shows that majority of farmer [80%] agreed that climate change adversely effected the plant yield. About 55% farmers change their crop pattern due to climate change which has also a negative impact on their earning. The incidences of crop diseases imposing an additional expense of pesticides' on farmers also increase due to climate change. Those farmers who carried out crop rotation have positive impact on the overall crop yield.

**Kumar et al. (2017)** tells that Climate change is a worldwide critical issue now a day. As climatic element act as direct input in agriculture, any change in its variable will definitely influence the agricultural production. Haryana is basically an agro-based state. It has around 45% of its population and 85% of its total land under cultivation. According to a study, an increase in winter temperature of 0.5 °C would reduce 10% of wheat production. Haryana is facing the problem of water shortage due to overall decrease in rainfall. The study reflect that rise in average temperature reduces the amount of rain fall which further result in decline in

agriculture production. The study shows that 0.1% decrease in rainfall will reduce 1.25% of total crop production. The study is based on secondary data taken from different government department. To mitigate the impact of climate change various programmes like crop insurance, use of hybrid seeds, earlier warming system and water conservation programmes may be adopted.

## RELATED ADAPTATION STRATEGY AND ACTION PLAN

**Goswami (2017)** explains that Global warming is the most important cause of climate change. According to WHO, pollution is responsible for 7 million premature deaths in the world per year. Extreme weather events are intensifying every year. Renewable energy can be a game changer in present situation. Many countries have already set a target of becoming 100% renewable. India also needs a strong action plan to reverse climate change and global warming. Carbon taxes can be introduced, incentives can be provided for adopting renewable energy programmes, national renewable energy policy can be developed which can make India a global renewable energy hub.

**Smit et al. (2002)** tells that adaption is an important component of climate change impact and vulnerability assessment in the field of agriculture. It also acts as policy response. Adaption is an important component of climate change response strategies. It varies in agriculture sector with respect to climate stimuli. The article develops a topology of agriculture adaptation option to climate change focusing on Canadian case. It analyzes the current knowledge about adaptation in agriculture. The article differentiates the adaptation option in agriculture according to involvement of various agents like production, industries, government etc. Adaptation option in Canada includes technological development, government programs and insurance, farm production practices and farm financial management. There is a need to better understand the relationship between potential adaption option and existing conditions.

**Stern (2008)** explains an appropriate way to examine the economics of climate change, suggest policy instruments and global action. Understanding the risks from different strategies is basic to an understanding of policy. The article focuses on the risks and how to reduce them on the cost of abatement. The top down macro

modeling of costs of emission reduction have been used to produce the cost around one percent of world GDP. The formal modeling and damage assessment is another important feature of policy making. The role of different policy making instruments like price oriented mechanism, technology etc are of great importance. An effective response must be organized globally to cope up the challenge of climate change. Adaptation will be necessary worldwide. Effective, efficiency and equity are the key features of global framework for climate change.

**Heal (2008)** explains recent developments which reflect conditions which need quick and strong action on climate change and the conditions where such actions are not justified. Many assumptions justify strong actions depending on choices of pure rate of time preference, elasticity of marginal utility, cost of climate change and nature of uncertainty and the way in which we react to this. There are many issues which are yet to be explored. More study is needed to evaluate the impact of climate change on our natural capital and the ways in which it may compromise with ecosystem. Uncertainty and risks are the dominating factors of climate change. The sustainability between produced goods and services and ecosystem requires models that are more disaggregated and represent more satisfactorily the issues raised for equity at the international level.

**Dessai et al. (2009)** emphasized the need of accurate climate predictions for decision making related to adaptation. Predictions can be useful for decision making if its skill is known to us. If the decision makers have the experience of using the predictions, the time period of predicted event is short with limited alternatives; the outcomes are well understood in terms of well constrained uncertainties but over precise climate prediction may lead to bad decisions. The recent World Modeling Summit for Climate Prediction called for a substantial increase in computing power increase by a factor of 1000 in order to provide better information at the local level. Adaptation strategies can be developed for greater understanding of the vulnerability of climate influenced decisions. There are alternatives to base adaptation decisions over the predicted future climate.

**Benestad et al. (2016)** states that many climatic researches agreed on anthropogenic global warming but a great number of researches still doubted the anthropogenic cause behind the process of climate changing. Most of these research paper starts with false assumptions. They ignore the contextual

information and physical interdependencies. False dichotomy was also a major reason behind the denial of anthropogenic global warming. The papers selected for study have a gap in perception on anthropogenic climate change between general public and climate scientist. The main objective is to learn from the mistake. Agnotology can be a useful tool to explore topics where knowledge has been contested by different people. The scientific way of thinking can resolve unanswered questions by providing valuable guidance when there are conflicting views.

**Arora et al. (2015)** states that human activity such as burning of fossil fuel, change in land use pattern etc plays important role in increasing greenhouse gases in the atmosphere. There is a need to develop a comprehensive climate change assessment to minimize the impact of climate change. Management of terrestrial carbon is required to mitigate climate change. Approximately 17-20% of global greenhouse gas emission is because of tropical deforestation, forest degradation and emission from land use change. Sustainable forest management and practices should be adopted to increase the carbon sequestration on forest land. Land use changes also influence the carbon management. In India mitigation options like improved energy efficiency, increasing use of bio mass energy, improved forest management can be much more cost effective means of reducing atmospheric carbon.

**World Bank (2018)** report discussed the impact of climate change on human beings. The World Bank climate change action plan emphasizes on climate smart agricultural investment plans. It helps the countries to meet the objective of Paris agreement. The World Bank is one of the largest financer of renewable energy projects, to adept and build resilience to climate change, to develop a new transport system, develop climate smart agriculture practice, investment and programs to preserve forest, sustainable city program. The world bank has initiated innovative partnerships like the Carbon pricing leadership coalition(CPLC), the Partership for market readiness(PMR), the Connect4Climate(C4C) to support capacity building to scale up climate change mitigation policies like carbon pricing can help incentives for transformational change.

**Kattimani (2016)** tells that many disasters like draught, flood, and hurricane are the result of increasing temperature of earth. Natural factors like continental drift,

solar activity, variation in earth orbit, volcanic eruption etc. are many factors of climate change. Man also plays an important role in changing the climatic conditions. The paper discussed various steps to reduce global warming and its impact. Fossil fuel use to generate electricity emits a large amount of greenhouse gasses. Saving electricity, reducing the use of plastic, stop deforestation and plant more and more tree, saving water etc. are the practices which are helpful in mitigating global warming. We all have equal responsibility of reducing the global warming and saving our environment.

**Louis et al. (2007)** describes the role of agroforestry in adapting and mitigating the impacts of climate change. Change in climate adversely affects the crop production, farming system and available natural resources. Subsistence agriculture of tropical regions is most vulnerable to climate change because of low adaptive capacity of the primitive farmers of that region. Agroforestry can provide an important opportunity for creating synergies between mitigation and adaptation. It can also reduce the accumulation of greenhouse gases. Transition from food crop into tree-based farming offers better prospects of livelihood. Agroforestry options may provide a means for diversifying production systems and increasing the sustain agility of smallholder farming systems.

## RELEVANCE OF THE PROPOSED TOPIC

Agriculture is the base of socio-economic structure of people of Haryana. Majority of people are either directly or indirectly engaged in agricultural activities. The different climatic phenomena influence the agriculture pattern and production therefore climate variability has been taken as the important parameter to study the changes occurring in this field. The study could be helpful in framing and implementing the measures to overcome the impact of climate variability.

## SIGNIFICANCE

1. My rural agriculture background of Rewari district where most of the people are still engaged in agricultural activities.
2. Despite being an agricultural dominant area, no related study has been carried out in Rewari district.
3. Analyses of plans and programs run by the government related to climatic variability in Rewari district have not been done.
4. As I am familiar with the area, it will be easy for me to gather the information required for the study more conveniently and accurately.

## OBJECTIVES OF THE STUDY

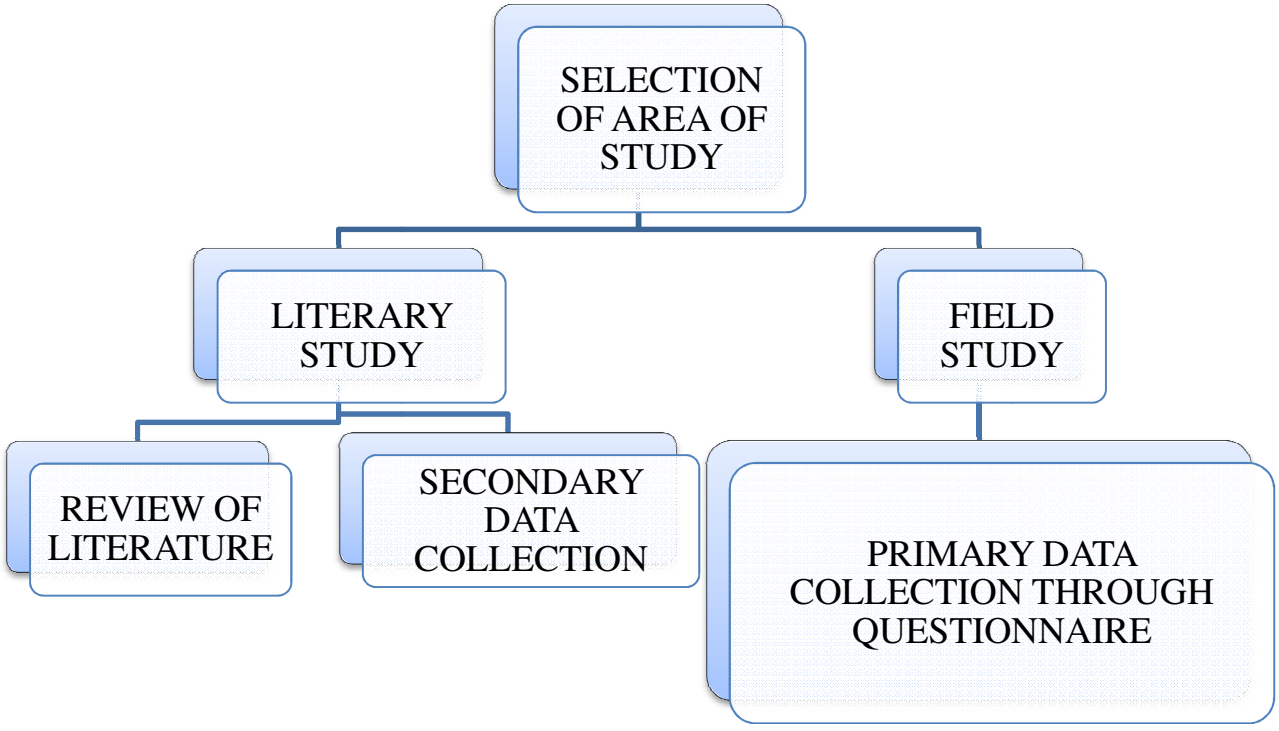
**1.** To understand the changing climatic scenario of Haryana with reference to Rewari district by analyzing the temperature and rainfall data from 1986 to 2017.
**2.** To study the impact of climate variability on selected Rabi crops in Rewari district.
**3.** To study the impact of climate variability on selected Kharif crops in Rewari district.
4. To evaluate the Indian government policies, plans, programs and adaptation strategies (with special reference to Haryana) for reducing the influence of climate variability on agriculture.

## HYPOTHESIS

$H_0$ -Climatic variability has no influence on the agricultural production in Rewari district of Haryana.
$H_1$ – Climate variability influences the Rabi and Kharif crop production in Rewari district of Haryana.

## METHODOLOGY

Data collection:
The research will be based on secondary data collected from government departments. The data related to climate will be collected from meteorological department and the crop production data will be obtained from agriculture department of Haryana. A survey will be conducted in Rewari district to collect the primary data. The data will be presented in graphical and statistical form through tables, graphs and maps.

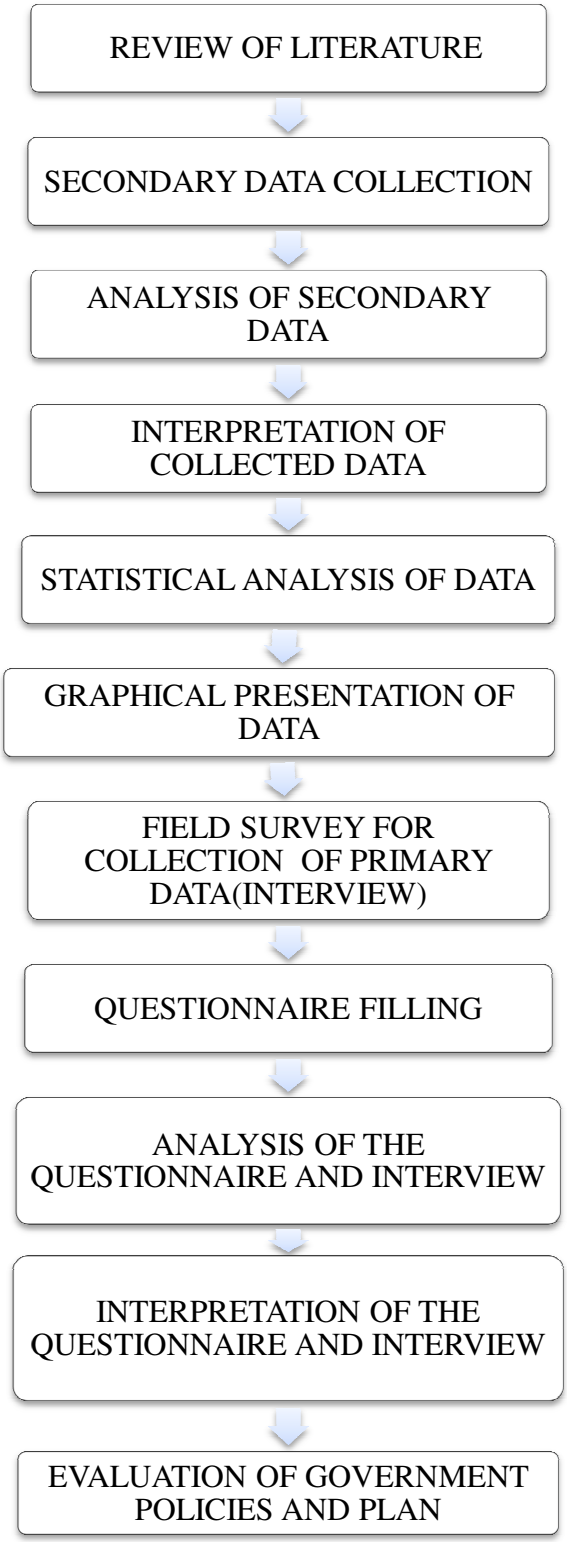


Data processing:
Statistical Package for the Social Sciences (SPSS Version 22) model will be used for statistical analysis of the collected data.

CASE STUDY

- A case study will be conducted to find out the response of farmers towards climate variability covering 30 farmers of five villages of each tehsil of Rewari district. A questionnaire will be prepared to collect the primary data.

# PLAN OF WORK


REVIEW OF LITERATURE
SECONDARY DATA COLLECTION
ANALYSIS OF SECONDARY DATA
INTERPRETATION OF COLLECTED DATA
STATISTICAL ANALYSIS OF DATA
GRAPHICAL PRESENTATION OF DATA
FIELD SURVEY FOR COLLECTION OF PRIMARY DATA(INTERVIEW)
QUESTIONNAIRE FILLING
ANALYSIS OF THE QUESTIONNAIRE AND INTERVIEW
INTERPRETATION OF THE QUESTIONNAIRE AND INTERVIEW
EVALUATION OF GOVERNMENT POLICIES AND PLAN

**TOPIC:**

**IMPACT OF CLIMATE VARIABILITY ON AGRICULTURE IN HARYANA - A CASE STUDY OF PRODUCTION OF SELECTED RABI AND KHARIF CROPS OF REWARI DISTRICT**

## CHAPTER -1

### INTRODUCTION

1.1 Climate Change
1.2 Climate Variability
1.3 Review Of Literature
1.4 Objective Of Study
1.5 Hypothesis
1.6 Methodology

## CHAPTER-2

### ENVIRONMENTAL BACKGROUND OF HARYANA

2.1 Physiography
2.2 Climatic Parameters
2.3 Temperature
2.4 Rainfall
2.5 Wind Velocity and Humidity
2.6 Soil and Land Use Pattern

## CHAPTER -3

### INDICATORS OF CLIMATE VARIABILITY IN HARYANA

3.1 Agro- Climatic Regions of Haryana
3.2 Variability Analysis of Rainfall

3.3 Seasonal Temperature Variations
3.4 Cropping Pattern of Haryana

**CHAPTER -4**
**IMPACT OF CLIMATE VARIABILITY ON CROP PRODUCTION IN REWARI DISTRICT**
4.1 Analysis of Rainfall and Temperature Variability
4.2 Impact of Climate Variability on Rabi Crop (Wheat) Production
4.3 Impact of Climate Variability on Rabi Crop (Mustard) Production
4.4 Impact of Climate Variability on Kharif Crop (Bajra) Production
4.5 Impact of Climate Variability on Kharif Crop (Cotton) Production

**CHAPTER -5**
**ADAPTATION STRATEGIES, PLANS AND GOVERNMENT POLICIES**
5.1 Evaluation of Government Action Plans on Adaptation with Special Reference to Haryana

**CHAPTER-6**
**CONCLUSION AND SUGGESTIONS**

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